esa
european space agency

SPACELAB-2

FIRST "PALLET-ONLY" FLIGHT

PRESS KIT

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Press and publications section:
8-10, rue Mario Nikis, 75738 Paris Cedex 15 - France
Tél.: 273-72-91 - Télex: ESA 202 746

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INTRODUCTION

ESA AND SPACELAB

With the ratification of its Convention, on 30 October 1980, the European Space Agency (ESA), which de facto came into being in May 1975, acquired its legal existence. The Agency groups in a single body the complete range of European space activities previously conducted by ESRO (European Space Research Organisation) and ELDO (European Launcher Development Organisation) in their respective fields of satellite development and launcher construction.

The eleven Member States of ESA are: Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Three other States are closely associated with the Agency: Austria and Norway have Associate Member status, and Canada has an agreement for close cooperation.

The Agency's purpose, as described in its Convention, is to provide for and to promote, for exclusively peaceful purposes, cooperation among European states in space research and technology, and their space applications, with a view to their being used for scientific purposes and for space applications systems.

The Agency's policy-making body is the ESA Council, composed of representatives of the Member States. The Council takes decisions on the policy to be followed by the Agency, and on scientific, technical, administrative and financial matters, each state having one vote (but none in the case of an optional programme in which it is not participating).

The Chief Executive and legal representative of the Agency is the Director General who is appointed by the Council for a defined period.

The ESA Headquarters is located in Paris, France, and has a staff of some 250 people. Its main technical centre, ESTEC, the European Space Research and Technology Centre, with a staff of about 810 people, is located at Noordwijk, in the Netherlands. Its Space Operations Centre (ESOC) is located at Darmstadt, Federal Republic of Germany, (staff: 220) and it has another centre (ESRIN) in Frascati, near Rome, Italy, which houses the Information Retrieval Service and the Earthnet Programme Office. The Agency also has a liaison office in Washington D.C.

During the decade 1973 to 1983, Spacelab was one of ESA's major programmes. This reusable research laboratory facilitiy which, when carried in the payload bay of the Space Shuttle orbiter, converts the Shuttle into a versatile, on-orbit research centre was designed, developed, funded and built by ESA as Europe's contribution to the NASA Space Transportation System Programme. Nine ESA Member States - Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Switzerland and the United Kingdom - and one Associate Member State - Austria, participated in the Spacelab Programme. ESA's project team, located at ESTEC, consisted of about 100 engineers at the peak of the development programme.

The first Spacelab mission, which was an outstanding success, took place between November 28 and December 8, 1983.

THE IMPORTANCE OF THE SPACELAB-2 MISSION

Spacelab is reusable and modular. It may be configured to fly with a given size of module and with a particular number of pallets. The total system consists of a "long" module (which can be converted to a "short" module by removing one of two identical cylindrical sections) and five pallets. Two verification flights are required to prove the System. The SL-1 configuration was a long module plus pallet so the module plus pallet mode of operation was verified. SL-2 will use the arrangement of 3 pallets and will verify the pallet-only mode. When Spacelab is used in the latter mode, the essential subsystems (such as the computers and data handling equipment) are housed in an "igloo". This provides a pressurized and thermally controlled environment. The experiments mounted on the pallet are controlled from the aft flight deck of the orbiter. The solar telescopes carried on the SL-2 flight require accurate pointing to certain parts of the Sun. This pointing is ensured by mounting them on the Instrument Pointing System (IPS) which provides arc sec pointing. Since the IPS is very sensitive to crew motion, the pallet-only mode is ideal for its delicate operation. It will take up a whole pallet and is controlled by the crew via the subsystem computer. Its design and manufacture has presented ESA and European industry with an important technological challenge and over 50 Million dollars has been expended by Europe on this sophisticated system.

The SL-2 flight sees the first use of the pallet-only mode of Spacelab and represents the first-flight of the IPS which provides an essential service for the Spacelab user. For ESA and NASA it is therefore, a very important step along the road to full utilisation of the Space Shuttle and Spacelab capabilities.

VERIFICATION OF SPACELAB IN ITS PALLET-ONLY MODE

The primary purpose of the second Spacelab mission is:

- To verify the performance of Spacelab systems and subsystems, including the Instrument Pointing System, in the pallet-only configuration.
- To obtain scientific and technology data and thus to demonstrate the capability of Spacelab to support multidisciplinary investigations.

A Verification Flight Test (VFT) programme has been developed by MSFC and will be implemented by JSC to accomplish this objective.

Specifically, the programme as carried out on STS 51F/Spacelab-2 (and previously on STS 9/Spacelab 1) is designed to verify the Spacelab system and the performance capabilities of its subsystems; to verify the compatibility of the Spacelab with the orbiter and with the experiments to be conducted on board; and to measure Spacelab induced environment during ascent, activation, deactivation and descent.

A set of special instrumentation, called Verification Flight Test Instrumentation (VFI), and standard orbiter and Spacelab operational instrumentation, will be used to gather data on Spacelab's performance during the mission. VFI sensors situated throughout the Spacelab and Orbiter will provide information on how well the Spacelab itself responds to the demands of flight.

Special tests, involving the Spacelab subsystems (particularly the IPS), will be conducted during the flight. Additional data will be gathered from normal subsystem and experiment operations.

The following is a description, by category, of the specific VFT objectives for STS 51F/Spacelab-2, which will complete the verification of Spacelab for the Pallet-only mode and the IPS in detail.

Environmental Control Subsystem

Evaluate the performance of the environmental control subsystem (ECS) during the mission including ECS interfaces with the Orbiter.

Structural Subsystem

Evaluate the performance of the structural subsystem during the mission including the Spacelab/Orbiter attachment system.

Command and Data Management Subsystem Software

Evaluate the performance of the subsystem computer operating system (SCOS) and the experiment computer operating system (ECOS) software including interfaces with the Orbiter general purpose computer (GPC) software.

Command and Data Management Hardware

Evaluate the performance of the command and data management subsystem (CDMS) hardware during the mission including the data processing subsystem, data acquisition subsystem, and associated Spacelab/Orbiter interfaces.

Electrical Power Distribution Subsystem

Evaluate the performance of the Spacelab electrical power distribution subsystem (EPDS) including the Spacelab/Orbiter electrical power interfaces.

Mass Properties Assessment

Establish the "as flown" Spacelab systems mass properties for the mission.

Habitability Assessment

Evaluate the flight crew habitability provisions during the mission including the general architecture, mobility aids, control and displays, and inflight maintenance provisions.

Safety Assessment

Evaluate performance and adequacy of safety critical subsystems, items, and operations during the mission.

Materials Assessment

Evaluate Spacelab systems materials compatibility with spaceflight environment.

Contamination and Radiation Assessment

Evaluate contamination and radiation levels experienced during the mission.

Instrument Pointing Subsystem

Evaluate the performance of the Instrument Pointing Subsystem (IPS) from both a hardware and software standpoint. In particular, IPS will be verified for:

- Activation and deployment using the CDMS for commands and monitoring
- Target acquisition and functional pointing under "Zero-g" conditions and CDMS control
- Quiescent stability and disturbance effects due to crew motion and vehicle induced disturbances
- Constant rate tracking while the Orbiter is in free drift up to limits of IPS range
- Solar offset pointing
- Scan mode
- Inertially fixed fine pointing mode using Gyro hold
- Manual control operation
- Contingency stowage using the Contigency Control Panel
- Deactivation and stowage using the CDMS for commands and monitoring

THE SPACELAB-2 MISSION

The Spacelab-2 mission will be the first flight of Spacelab in its "pallet-only" mode and the second and final verification flight of the European space laboratory system. The Spacelab-2 configuration will consist of a two-pallet train and a single pallet.

Spacelab-2 is scheduled for launch, in the cargo bay of the orbiter "Challenger" from Kennedy Space Center at 15:00 hours local time (19:00 hours GMT), on 12 July 1985.

During its seven day mission, it will orbit the Earth at an altitude of approximately 390 kilometres with an inclination of 50° to the Equator. It is scheduled to land at Edwards Air Force Base (California) on 19 July, unless, of course, the mission is extended beyond the original seven days.

The Spacelab-2 mission is designed to capitalize on several Shuttle-Spacelab capabilities; in particular, to carry very large instruments, and to point several instruments independently with accuracy and stability. The experiments to be carried out during the mission are mainly in the fields of astronomy for which the pallet-only mode is particularly suitable.

Mission success depends on active crew involvement in experiment operations, with the benefit of close communication between scientists working in space and scientists on the ground. These unique advantages of Spacelab for supporting instruments and scientists make it possible to do sophisticated research in space.

The centre of activity throughout the mission is the Payload Operations Control Centre - the POCC - at JSC from where all payload operations are managed. Representatives of the science teams responsible for the different experiments on board Spacelab work around the clock in the POCC maintaining permanent contact with the payload specialists either by means of computers or through video and voice communication links.

SPACELAB-2: THE HARDWARE

Pallets

The pallet cross-section is U-shaped providing hard points for mounting heavy experiments and a large panel surface area to accommodate lighter payload elements. Pallet segments are 3 m long and 4 m wide and can be flown independently, or interconnected in a pallet 'train'. The pallet train cannot consist of more than three segments, whereas the independent configurations may consist of one to five pallet segments. Spaced pallet segments are connected via a utility support structure.

In pallet-only configurations, subsystem equipment necessary for the operation of Spacelab is located in the 'igloo', which is mounted on the front frame of the first pallet segment.

Twenty four inner and 24 outer panels, made of aluminium alloy honeycomb, cover the frame. The inner panels are equipped with threaded inserts so that payload and subsystem equipment can be attached. Each panel can support a uniformly distributed load up to 50 kg/m2.

Twenty four standard hardpoints made of chromium-plated titanium casting are provided for payloads which exceed the acceptable loading of the inner panels.

Payloads will normally fit within the pallet, but it is possible to carry special payloads which overhang the sides if the necessary arrangement can be made to fix them.

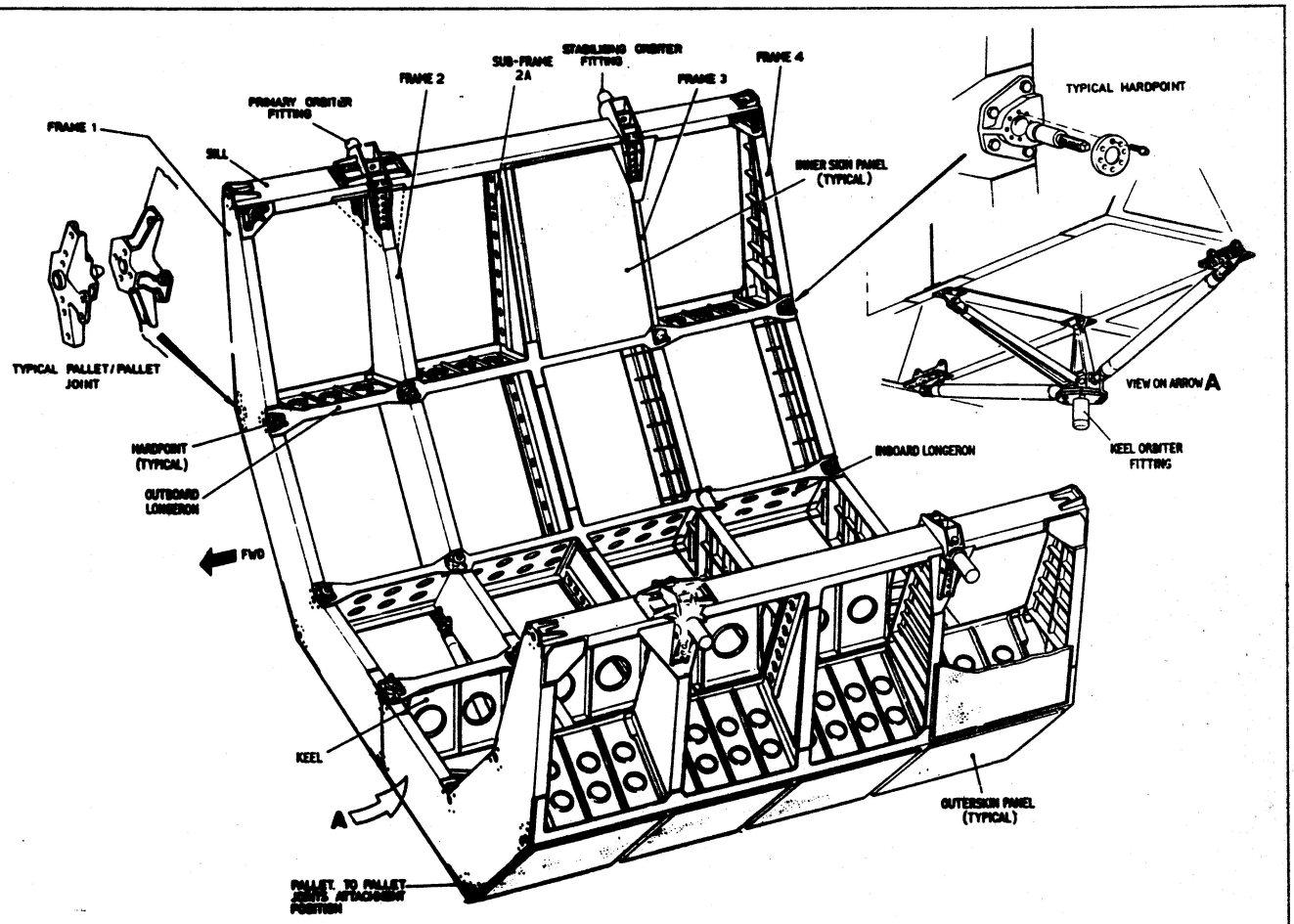
The Igloo - the unmanned service module for pallet-only Spacelab missions

A main part of the modular Spacelab system is a pressurized automatic supply module, the "Igloo" for pallet-only flight configurations. Normally Spacelab subsystem equipment is housed in the core segment of the module. When the module is not being flown, it is of course necessary to house the subsystems elsewhere. As the subsystems are designed for a pressurized environment, the Igloo structure has been developed as a pressurized compartment in which Spacelab subsystem equipment can be mounted in a dry air environment at normal earth atmospheric pressure. The Igloo is designed for seven-day missions, but could, if necessary, be used for missions of up to 30 days.

The Igloo is always attached vertically to the forward end frame of the first pallet in the pallet-only mode.

The primary structure is a cylindrical, locally stiffened shell, made of aluminium alloy forged rings, and closed at one end. The other end has a mounting flange for the cover. A seal is inserted when the two structures are joined together mechanically to form a pressure tight assembly.

Externally the primary structure has fittings for the structure by which it is fastened to the pallet, for handling and transportation on the ground, and for the passive thermal control insulations. Two feedthrough plates accommodate utility lines and a pressure relief valve. Internally there are mounting facilities for subsystem equipment and the Igloo secondary structure. The weight of an equipped Igloo is approximately 665 kg, and 2.2 m3 is available for subsystems.



Pallet segment

The cover is also a cylindrical shell, made of welded aluminium alloy and closed at one end. Adaptors for the positive relief valve and the burst disc are sited on top of the cover. The cover can be removed to allow full access to the interior.

Subsystem equipment is mounted on the secondary structure which also acts as a guide for the removal or replacement of the cover. The secondary structure is hinge-fastened to the primary structure allowing access to the bottom of the secondary structure and to equipment mounted within the primary structure.

The Igloo is mounted on the pallet by a cross beam and two adjustable link fittings. A set of Spacelab subsystem equipment, similar to the set integrated in the module, is installed within the Igloo in the pallet-only configuration. The only operator interface for the pallet-only configuration is through the Spacelab equipment in the Orbiter aft flight deck, i.e., Data Display Unit, keyboard and control panels. This equipment is installed for all Spacelab configurations.

The following equipment (basic and mission dependent) is located in the Igloo:

- 3 computers (subsystem, experiment and back-up computer)
- 2 Input/Output units (subsystem and experiment Input/Output)
- 1 mass memory
- 2 subsystem Remote Acquisition Units.
- 9 interconnecting stations
- 1 emergency box
- 1 power control box
- 1 subsystem power distribution box
- 1 remote amplifier and advisory box
- 1 high rate multiplexer
- freon cooling loop components

In addition to the Igloo the following major subsystem equipment is also mounted to the front frame of the first pallet segment:

- 1 subsystem 400 Hz inverter
- 1 experiment 400 Hz inverter
- freon cooling loop components

Thermal control of the 400 Hz inverters is also achieved by cold plates connected to the pallet freon cooling loop.

Instrument Pointing System (IPS)

The Instrument Pointing System IPS is a versatile pointing system for use on the Orbiter to provide precision orientation capability to any scientific experiment requiring essentially better pointing accuracy and stability than that provided by the Orbiter.

With its three-axis gimbal system it can orient payloads of up to 2000 kg within an accuracy of 1 arc sec.

The IPS development under ESA contract was completed in 1984.

System Description

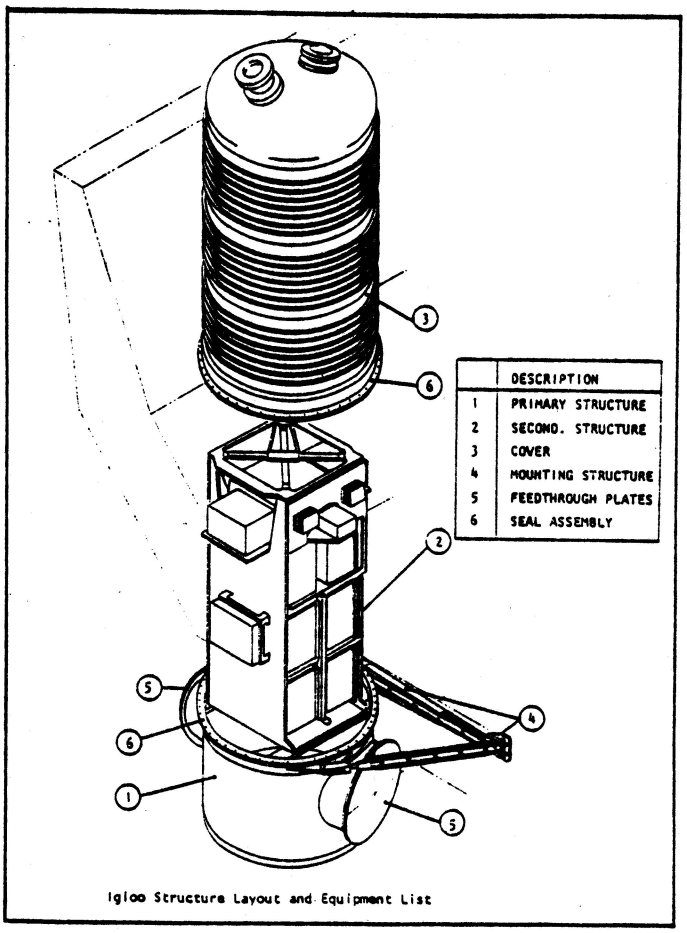
The IPS is a Spacelab subsystem taking full advantage of the system resources and services without using any of the payload-dedicated support. Located in a standard SL-Pallet, it comprises a three axis gimbal system end-mounted to the payload, the Payload Clamp Assembly to support the payload during ground operations and load-critical flight phases, and the control electronics to provide the full operational flexibility during all mission phases and to execute the pointing control operation via the Spacelab subsystem computer.

The dimensions of the payload are only restricted by the width of the Pallet and the available length of the Pallet train or cargo bay. Accommodation of different payload dimensions can be performed by variation of the clamp unit locations and by adaptation of the gimbal centre of rotation accordingly by replacement of mission dependent structural elements.

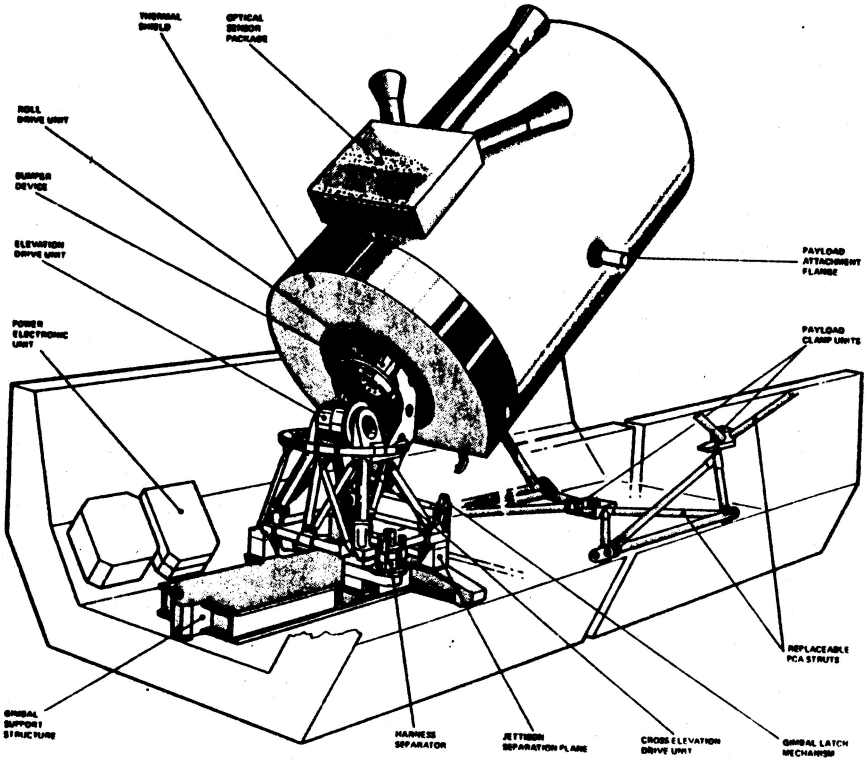
The three identical Drive Units consist of a main shaft supported by precision ball bearings within a titanium housing and controlled by two redundant brushless torquers and resolvers.

The front end of the Roll Drive Unit is connected to the Equipment Platform, a honeycomb disk of 2 m diameter, which carries all subsystem dedicated electronic boxes and a redundant mechanism which provides, in orbit, the rigid attachment between the payload and the gimbal system and which decouples both during all load generating flight and ground phases.

The IPS is thermally controlled by application of an active heating system on the critical components and a combination of insulated and radiating areas to control the heat exchange to its environment in an optimal way during all critical hot and cold operations. During launch and landing phases the payload will be supported by three attachment flanges within the Payload Clamp Assembly. For on-orbit stowage the Payload Attachment Flanges will be shifted by the Payload Gimbal Separation Mechanism on the Equipment Platform into three Payload Clamp Units.



Igloo Structure Layout and Equipment List



Command and data management system

THE PAYLOAD

During the Spacelab-2 mission, 13 experiments will be carried out in 7 scientific disciplines:

- solar physics
- atmospheric physics
- plasma physics
- high energy astrophysics
- infrared astronomy
- technology research
- life sciences

Several major new scientific instruments will fly for the first time and four items are making their second flight. During the next decade, many of the Spacelab-2 instruments will be used routinely in this remarkable laboratory.

Amongst the experiments are two from the United Kingdom. It must, however, be stressed that ESA is in no way involved in these payload elements; they have been developed with UK money and have been integrated and will be flown at NASA's expense.

The two experiments are:

Coronal Helium Abundance Spacelab Experiment (CHASE)

(PIs: Dr. Gabriel, Rutherford Appleton Laboratory and
Dr. Culhane, University College, London)

The objectives of this experiment are to:

- o Determine the relative abundance of helium to hydrogen in the solar corona
- o Measure the distribution of electron temperature and density and the abundances of iron and oxygen above the solar limb
- o Investigate the variation of the above effects as a function of distance from the Sun to evaluate the onset of solar wind effects

The CHASE instrument, a 28 cm. focal length, grazing incidence telescope and spectrometer, weighs about 150 kg. It uses electron multipliers as detectors and observes in the 150 to 1335 A range. It is mounted on the IPS to ensure accurate pointing at the Sun and its environment.

The value of the relative abundance of helium to hydrogen in the Sun's atmosphere is believed to be representative of the interstellar gas at the time the Sun was formed. It may even indicate the amount of helium produced in the Big Bang origin of the universe. It is, therefore, an important experimental test of different cosmological models.

Hard X-ray Imaging of Clusters of Galaxies and Other Extended X-ray Sources (XRT)

(PI: Prof. Willmore, University of Birmingham)

The objective is to investigate the spatial and spectral distribution of X-ray fluxes from clusters of galaxies in the energy range 2-20 keV.

The experiment uses two X-ray telescopes mounted on the middle pallet. Multiwire position sensitive proportional counters are the detectors and its own pointing system using motorised gymbals will be used.

The telescopes are about 2 metres long and the total weight of the experiment equipment is about 280 kg. The telescope system incorporates coded binary masks with different resolutions. The spectral feature between 6 and 7 keV that is associated with iron will be observed in detail.

The American experiments are:

Solar Magnetic and Velocity Field Measurement System

Solar Optical Universal Polarimeter (SOUP)

(PI: Dr. Alan M. Title, Lockheed Solar Observatory, Palo Alto, California)

Purpose: The objective of this investigation is to observe the strength, structure, and evolution of magnetic fields in the solar atmosphere and to determine the relationship between these magnetic elements and other solar features.

The Solar Optical Universal Polarimeter is an elaborate instrument set. The assembly mounted on the Instrument Pointing System houses a 30 centimetre (12 inch) Cassegrain telescope, a video camera with a tunable filter system, a white-light video camera, a video processor, and two film cameras. The telescope is mounted on movable legs that allow SOUP to observe any point of the sun while the Instrument Pointing System is aimed elsewhere on the solar disc. A fine guidance system keeps the image extremely stable for the cameras. A separate electronics box, to aid in telemetering data to the ground, is mounted on the first pallet.

Solar Ultraviolet High Resolution Telescope and Spectrograph (HRTS)

(PI: Dr. Guenter Brueckner, Naval Research Laboratory, Washington, D.C.)

Purpose: This experiment studies features in the sun's outer layers; the chromosphere, the corona, and the transition zone between them.

The HRTS instrument includes a 30 centimetre (12 inch) telescope with a spatial resolution of one-half arc second (approximately 360 kilometres/223 miles on the solar surface). The telescope focuses a 4.5 centimetre (1.8 inch) solar image through the slit of a spectrograph, which then resolves the image into different wavelengths and records them on film.

Solar Ultraviolet Spectral Irradiance Monitor (SUSIM)

(PI: Dr. Guenter Brueckner, Naval Research Laboratory, Washington, D.C.)

Purpose: The objective of this investigation is to determine both long-term and short-term variations of the total ultraviolet flux emitted by the sun.

The Solar Ultraviolet Spectral Irradiance Monitor specifically measures solar radiation in the ultraviolet wavelength range from 1200 A to 4000 A. SUSIM is operated automatically every time the Instrument Pointing System is aimed at the sun.

The instrument is equipped with redundant spectrometers and detectors to determine any change in its sensitivity during the solar exposure in orbit.

Ejectable Plasma Diagnostics Package (PDP)

(PI: Dr. Louis A. Frank, University of Iowa, Iowa City, Iowa)

Purpose: This investigation uses instruments on a subsatellite to study natural plasma processes, orbiter-induced plasma processes, and beam plasma physics.

Fourteen instruments are mounted on the Plasma Diagnostics Package (PDP) subsatellite for measurements of various plasma characteristics; such as low energy electron and proton distribution plasma waves, electric field strength, electron density and temperature, ion energy and direction, and pressure of uncharged atoms.

Spacelab-2 is the second flight of the Plasma Diagnostics Package, which operated successfully during the third Shuttle mission.

Vehicle Charging and Potential Experiment (VCAP)

(PI: Dr. Peter M. Banks, Stanford University, Stanford, California)

Purpose: The aim of this investigation is to study the ionosphere's natural traits by perturbing it with beams of electrons.

The Vehicle Charging and Potential investigation uses four instruments. An electron generator, mounted on the first pallet, emits electrons in a steady stream or in pulses of varying durations. It is pointed perpendicular to the orbiter payload bay, but electron emissions will spiral along the magnetic field lines. By calculating the position of the magnetic field at a given time, investigators can control the direction of the electron beam.

Three plasma probes mounted on a shelf on the second pallet are used to measure the effects induced by the emitted beam.

The VCAP experiment operated successfully during the third Shuttle mission. During the Spacelab-2 mission, more sophisticated research can be performed based on information from the previous flight, and first-time studies of beams at great distances from the Shuttle can be attempted.

Plasma Depletion Experiments for Ionospheric and Radio Astronomical Studies

(PI's: Dr. Paul A. Bernhardt, Los Alamos National Laboratory, Los Alamos, New Mexico and

Dr. Michael Mendillo, Boston University, Boston, Massachusetts)

Purpose: This investigation uses the Shuttle as an active experimental probe to create artifical "holes" in the ionosphere. At the same time, ground based observatories use radio and optical observing techniques to study the plasma characteristics of the holes and to conduct radio astronomical studies through them.

Shuttle thruster firings are made over prescribed ground sites to release from 130 to 1300 kilograms (300 to 3000 pounds) of exhaust vapours, consisting primarily of water. During the exhaust release, scientists at ground based observatories watch for the appearance of resultant "holes" in the ionosphere.

Elemental Composition and Energy Spectra of Cosmic Ray Nuclei Between 50 GeV/Nucleon and Several TeV/Nucleon

Cosmic Ray Nuclei Experiment (CRNE)

(PI's: Dr. Peter Meyer and Dr. Dietrich Müller, University of Chicago, Chicago, Illinois)

Purpose: The objective of this investigation is to study the composition of high-energy cosmic rays by using a large instrument exposed to space for a considerable period of time.

Cradled by a special support structure at the end of the Spacelab pallet train, the cosmic ray detector is exposed to space during the entire seven-day mission. The egg-shaped instrument shell is filled with layers of detectors. Particles enter through both ends of the instrument, but only those entering the space-exposed end are measured.

A Small Helium-Cooled Infrared Telescope (IRT)

(PI: Dr. Giovanni G. Fazio, Smithsonian Astrophysical Observatory, Cambridge, Massaschusetts)

Purpose: The objective of this investigation is to measure and map diffuse and discrete infrared astronomical sources while evaluating the Space Shuttle as a platform for infrared astronomy. As the same time, a new, large superfluid helium dewar system for cooling the telescope will be evaluated.

The 900 kilogram infrared telescope is located on the third Spacelab pallet. It is a Herschelian telescope, which uses a single 15 centimetre (6 inch) diameter mirror to focus the radiation onto detectors located to one side. The telescope is highly baffled to avoid exposure to natural and Shuttle-induced background radiation. The focal plane of the telescope has 9 detectors, covering the wavelength region from 4 to 120 microns (1 micron equals 10 000 A) in 4 broad spectral bands and 1 narrow band. A tenth detector, operating in the range between 2 and 3 microns, is used for locating known stars. A drive motor moves the telescope at an angular speed of 6° per second and covers a 90° arc across the sky.

Properties of Superfluid Helium in Zero-Gravity

(PI: Dr. Peter V. Mason, Jet Propulsion Laboratory, Pasadena, California)

Purpose: The objectives of this investigation are to determine the fluid and thermal properties of superfluid helium, to advance scientific understanding of the interactions between superfluid and normal liquid helium, and to demonstrate the use of superfluid helium as a cryogen in zero-gravity.

The main dewar is an insulated container filled with 100 litres (26 gallons) of superfluid helium. Throughout the mission, a variety of sensors inside the container monitor the properties of the helium. Very precise sensors measure the temperatures of the dewar, the porous plug and the insulation.

Vitamin D Metabolites and Bone Demineralization

(PI: Dr. Heinrich K. Schnoes, University of Wisconsin, Madison, Wisconsin)

Purpose: This investigation measures the vitamin D metabolite levels of crew members to gain information on the causes of bone demineralization and mineral imbalances that occur during prolonged spaceflight as well as on Earth.

This investigation has two phases, a development phase and a final phase. The development phase includes extensive testing before flight, and the final phase involves the postflight analysis of the crew's blood samples.

In flight, 25 millilitres (0.75 ounces) of blood are taken from each of the crew members both early and late in the mission. A standard life sciences blood collection kit is used by the crew members to draw blood from each other. The blood samples are placed in a centrifuge to separate the plasma from the blood cells, and the plasma is stored in a freezer for the rest of the flight. All equipment is stored in a mid-deck locker. In the final phase, upon return to Earth, the frozen plasma is analyzed for D-metabolite levels and compared to samples of plasma taken from crew members before flight.

Gravity-Influenced Lignification in Higher Plants

Plant Growth Unit (PGU)

(PI: Dr. Joe R. Cowles, University of Houston, Houston, Texas)

Purpose: The purpose of this investigation is to determine the effects of microgravity upon the production of lignin in higher plants.

Young plant seedlings are grown in enclosed chambers ressembling terrariums. These growth chambers are inside two plant growth units, which have their own lighting, thermal control, power, and instrumentation.

Mung beans are planted in four chambers and pine seedlings are planted in eight chambers just before launch. The mung beans are planted just prior to launch so that they germinate in space. Half of the pine seedlings are four days old, as were the pine seedlings flown previously, and half are ten days old. Investigators are growing the ten-day old seedlings to see if lignin reduction is greater in the older plants than in the younger ones.

The growth chambers are sealed and the atmosphere of each chamber is exchanged with gas mixtures containing known amounts of oxygen and carbon dioxide. Shortly before launch, the chambers are loaded into the plant growth units, transported to the launch pad, and installed in locker spaces in the Shuttle mid-deck.

After the analysis, an identical group of plants will be grown on the ground as controls. Temperature profiles obtained on orbit will be recreated for a temperature environment similar to the one experienced by the flight plants. The lignin content and other characteristics of the controls will then be compared with the Spacelab-2 specimens.

INTEGRATION ACTIVITIES

Final system integration activities for the Spacelab-2 mission began in autumn 1984 when the pallets were moved into a test stand at Kennedy Space Center (KSC) for final payload installation. At the same time, the Instrument Pointing System (IPS), which had been shipped from Europe to the United States in November 1984, was integrated, installed on the pallet and checked out.

In early May 1985, the pallets with the payload and IPS installed, were moved to the cargo integration test equipment stand in the Operations and Check-out Building in KSC for orbiter/cargo interface check-out. The next step took place on 8 June with the transfer of the complete cargo (pallets + payload + IPS) to the Orbiter Processing Facility for installation in Challenger's cargo bay. This operation was successfully completed on June 9 and Spacelab-2/Orbiter interface verification testing began on June 10.

One vital test will take place before the Orbiter and its cargo are moved to the Vertical Assembly Building (VAB), namely, the "end-to-end" test designed to check the communication link between Johnstone Space Center, where both the Mission Operations Control Room and the Payload Operations Control Centre are located, and the orbiter (in KSC) via the Tracking and Data Relay Satellite System (TDRSS).

At the end of June, the Orbiter, in its upright position, will be installed on the launch pad for final preparations prior to the launch on 12 July.

THE SPACELAB-2 CREW

The seven-member Spacelab-2 crew includes a commander, a pilot, three mission specialists - all assigned to the mission from NASA's astronaut corps - and two payload specialists who are professional scientists. The commander, pilot, and one of the mission specialists are responsible for the smooth operation of the Shuttle. These three are considered the orbiter flight crew.

The two payload specialists and the remaining two mission specialists work together as the Spacelab-2 science crew. To ensure maximum scientific return, they work around the clock in 12-hour shifts, with one payload specialist and one mission specialist on each shift. The payload specialists are responsible for performing Spacelab-2 investigations. The mission specialists are career astronauts with scientific expertise, whose role is to operate Spacelab systems as well as science instruments.

Flight Payload Specialists

Dr. Loren Acton is a co-investigator for the Spacelab-2 solar magnetic and velocity field investigation. He has a Ph.D. in astro-geophysics from the University of Colorado. Dr. Acton's active career in solar research includes 21 years within the space astronomy research programme at the Space Sciences Laboratory of Lockheed Palo Alto Research Laboratory in California. Dr. Acton has been a principal investigator on ten solar rocket experiments and a co-principal investigator for an instrument that is currently studying the sun from the Solar Maximum Mission satellite.

Dr. John-David Bartoe is a co-investigator for two of the Spacelab-2 solar investigations. He participated in the design of the instruments, and he served as project scientist for the development of one of them, the solar ultraviolet telescope. With a Ph.D. in physics from Georgetown University; Dr. Bartoe is currently a supervisory astrophysicist at the U.S. Naval Research Laboratory in Washington, D.C., where he has performed solar research for almost 20 years. He has carried out several solar ultraviolet studies with sounding rockets, satellites, and instruments flown on Apollo and Skylab missions.

Mission Specialists

Dr. Anthony England is a geophysicst with a Ph.D. in earth and planetary sciences from the Massachusetts Institute of Technology. He was selected as a scientist-astronaut by NASA in 1967 and subsequently served as a support crew member on two Apollo flights. For several years in the mid-1970's, Dr. England worked as a research geophysicist with the U.S. Geological Survey and then returned to NASA as a mission specialist. Since 1979, he has participated in the development of Shuttle and Spacelab missions.

Dr. Karl Henize is an astronaut who was selected as a scientist-astronaut in 1967. He has a Ph.D. in astronomy from the University of Michigan and has been asssociated with various observatories in the United States and abroad. Dr. Henize was a support crew member on Apollo and Skylab missions and was the principal investigator for an ultraviolet telescope flown on Skylab. He is now a member of a team developing a Shuttle telescope for ultraviolet and optical astronomy.

Flight Crew

C. Gordon Fullerton (Colonel, USAF), the Spacelab-2 commander is responsible for overseeing the entire mission. He was the pilot for the third Shuttle mission and has more than 15 years of experience as an astronaut. Col. Fullerton has an M.S. in mechanical engineering from the California Institute of Technology.

Roy D. Bridges, Jr. (Colonel, USAF) the Spacelab-2 pilot, assists the commander with Shuttle operations. He was selected as an astronaut candidate by NASA in 1980. He has an M.S. in astronautics from Purdue University.

Dr. Story Musgrave has almost 20 years of experience as a NASA scientist-astronaut. He earned an M.D. from Columbia University, and he has participated in the design of NASA's spacesuits and life support equipment. Dr. Musgrave was a mission specialist on the sixth Shuttle flight. On the Spacelab-2 mission, he works with the commander and pilot to handle the busy schedule of Shuttle operations.

SPACELAB GENERAL INFORMATION

THE SPACELAB SYSTEM

Spacelab is a laboratory in which scientists can perform experiments in space. It allows them to use ordinary laboratory equipment in space in a manner that is not possible with conventional automated satellites. Spacelab has therefore been designed to provide the essentials for doing this. These are:

(i) the capability to transport and house an adequate mass and volume of equipment;
(ii) the provision of power and the thermal control for that equipment;
(iii) the means of sending command signals to the experiments, and of obtaining data from the experiments;
(iv) the supply of suitable specialised equipment, such as airlocks and pointing systems for instruments;
(v) the provision of a computer system and associated software for managing the supporting subsystems, the experiments and, particularly, the flow of data;
(vi) the presence of Man to oversee the operation of the subsystems and experiments, to intervene in the experiments if necessary, and to repair faulty equipment.

These provisions are presented to the experimenter in a standard way, so that he can use them much as he does in his own laboratory.

Spacelab is a large and well-equipped laboratory - much larger than the Apollo and Mercury capsules - and much more sophisticated than the Skylab of 10 years ago. Whereas Skylab used existing space hardware, Spacelab is the first purpose-built space laboratory.

Spacelab's modular construction is based on two essential elements - the module and the pallet. The sizes of both module and pallet are adjusted to suit a particular mission. The module is cylindrical, 4 metres in diameter, and consists of either one or two 2.7 metre-long segments enclosed between end cones. The configuration is called a 'short module' or a 'long module' depending on the number of segments used. The overall lengths are about 4.3 metres and 7 metres, respectively. The module fits into the cargo bay of the Space Shuttle. It is fixed at the bottom of the bay and inside the sides.

The single segment in the 'short module' is the 'core segment'. This contains the Spacelab subsystems which provide the crew with all the necessary laboratory facilities. Eight cubic metres of the core segment are available for equipment for the experiments. If more space is needed for the experiments, a second segment is added to the core segment. This 'experiment segment' is dedicated solely to experiments and provides a further 14.6 cubic metres for housing equipment. In the module, experimental equipment is housed in standard racks that take the usual
19-inch (48-centimetre) size laboratory equipment trays, or it is mounted centrally on the floor (centre aisle). The fixtures and connections for equipment are standard as far as possible.

The crew reach the module from the Orbiter cabin through a tunnel one metre in diameter. Both the tunnel and the module are kept at a comfortable temperature and humidity with a normal oxygen-nitrogen atmosphere. The crew can thus work 'in their shirt sleeves' under these Earth-like laboratory conditions.

A limited amount of Spacelab-related work can be carried out in the aft flight deck of the Orbiter. Computer terminals are available there for the scientist-astronauts so that they can watch displays duplicating those in Spacelab itself. The Spacelab crew can talk to each other, with the Orbiter crew, and with the ground-based experimenters, using a specially designed 'cordless' intercom. Closed-circuit television enables the crew to survey the Spacelab equipment.

The pallet is also modular, being built up of segments 3 metres long and 4 metres wide. These may be mounted individually or up to three may be joined together to form a single 'pallet train'. The pallet cross-section is U-shaped.

Spacelab is extremely versatile because of the modular approach adopted. Variations upon the three basic flight configurations - module only, module and pallet, and pallet only - can be obtained by changing the number of module segments or pallet segments.

In the pallet-only mode, the essential subsystems such as computers and data-handling equipment (which are normally part of the core segment) are contained in an "igloo", ensuring a pressurised, temperature-controlled environment. The igloo is a cylinder 1.1 metres in diameter mounted to the front frame of the first pallet. Experimental equipment mounted on the pallet can be controlled from the module, from the aft flight deck of the Orbiter, or from the ground. Pallet-mounted experiments can also be adjusted by spacesuited members of the crew during 'spacewalks'.

The centre of gravity of the Spacelab-Orbiter combination must be strictly controlled so that safety is ensured when re-entering, flying within the atmosphere, and landing. Spacelab must therefore be placed towards the back of the cargo bay of the Orbiter.

The total mass of Spacelab and its payload is limited to 14 500 kilograms for landing. However, additional mass, such as equipment to be left in orbit, or consumables, may be carried at lift-off.

SPACELAB DEVELOPMENT

Under contract to ESA, MBB-ERNO (Bremen, Federal Republic of Germany) was responsible as prime contractor for the development, integration, testing, and delivery of Spacelab, as well as for the integration of the European part of the first Spacelab payload. MBB-ERNO headed an industrial consortium with partner companies from ten European countries. A so-called Development Fixture and an Engineering Model, to be used for all work in the Bremen integration hall, were developed and built for the development and test phases.

In its geometric dimensions, the Development Fixture corresponded to the later Flight Unit; it was, however, accessible from each side in order to check the routing of cable harnesses and supply lines. The Engineering Model was a prototype identical with the Flight Unit in configuration and design, and is now available to NASA as a ground version at the Kennedy Space Center.

The Spacelab-1 Mission

On its first mission, in 1983, Spacelab was flown in its module configuration, i.e., the long module, consisting of the core and experiment segments. The core segment was equipped with a control centre and the payload specialists' work bench racks as well as with experiment and system racks. The payload occupied the whole of the experiment segment including the airlock, through which cameras were directly exposed to the space environment. The configuration was completed by a pallet which accommodated the European Bridge Assembly equipped with experiments and measuring instruments.

Under contract to NASA, the U.S. company MDTSCO was responsible for integration of the Spacelab system. It was supported by the European Resident Team, which was composed of ESA and MBB-ERNO representatives and of representatives of all companies involved with the Spacelab programme.

During its first mission (November 28 - December 8, 1983), which was originally foreseen to last for nine days but which, since sufficient resources were available, was extended by a further day, Spacelab passed its qualification tests with flying colours. This success was confirmed during the second flight, the SL-3 mission, (April 29 - May 6, 1985) during which the long-module configuration was used for the second time.

Some Highlights of the Development Programme

1972: the European Space Conference, represented by the Ministers of Science and Technology of ESA Member States, decided to cooperate with the USA in the development of space systems within the framework of the Post-Apollo Programme.

1974: ESA awarded the development contract for Spacelab, Europe's contribution to the U.S. Space Transportation Systems programme, to an industrial consortium with MBB/ERNO (then VFW/ERNO) as prime contractor.

1980: The Spacelab prototype was delivered to NASA

NASA placed an order for a second Spacelab (identical reproduction of the qualified hardware).

1981: Flight Unit I (long module and one pallet) for manned missions was delivered to NASA.

1982: Flight Unit II (three pallets and an igloo) and the complete European payload for the first mission (experiments, measuring instruments and test specimens prepared by European scientists) was shipped to the USA.

INDUSTRIAL ORGANISATION

Contractors to ESA (for Spacelab development)

1. Prime Contractor

VFW-FOKKER ERNO (now MBB-ERNO) Federal Republic of Germany	Project management, system engineering, product assurance, integration, test operations, crew habitability, igloo, thermal control, miscellaneous Spacelab components and services.

2. Co-Contractors

AEG TELEFUNKEN INDUSTRIES Federal Republic of Germany	Electrical power distribution subsystem
AERITALIA Italy	Module structure, environmental and thermal control subsystem
BELL TELEPHONE MANUFACTURING CO. Belgium	Electrical systems ground support equipment (system level)
DORNIER SYSTEMS Federal Republic of Germany	Environmental control/life support subsystem
FOKKER The Netherlands	Scientific Airlock (common payload support equipment)
BRITISH AEROSPACE United Kingdom	Pallet structure
KAMPSAX Denmark	Computer software
MATRA France	Command and data management subsystem
SABCA Belgium	Igloo structure, utility bridge, common payload support equipment
SENER Spain	Mechanical ground support equipment

3. Sub-Contractors

AEG-ULM Federal Republic of Germany	Intercom system and Electrical Harness
AERITALIA Italy	Airlock manufacturing and handling equipment

Sub-Contractors (contd.)

BRUNSWICK United States	Nitrogen tank assembly
BRUNSWICK/CELESCO United States	Fire and smoke detector, fire suppression system
CARLETON United States	Hybrid system, atmospheric control assembly
CASA Spain	Mechanical Ground Support Equipment items
CII France	Computers and software
COMPAGNIE INDUSTRIELLE RADIO ELECTRONIQUE Switzerland	Simulators, orbiter interface adaptor
DORNIER SYSTEMS Federal Republic of Germany	Subsystem computer operating system coding
DRAEGER Federal Republic of Germany	Ground support equipment for environmental control life support
ELEC. ZENTR. Denmark	Pressure decay sensor
ERNO Federal Republic of Germany	Condensate storage assembly
ETCA Belgium	Measuring and stimuli equipment
HAMILTON STANDARD United States	Fan assembly, water separator, CO2 control assembly, humidity and temperature control assembly, pumps
INSTITUTO NACIONAL DE TECHNICA (INTA) Spain	Mechanical ground support equipment, lighting
MARTIN MARIETTA United States	Demultiplexer
MBB Federal Republic of Germany	Multiplexer
MICROTECNICA Italy	Thermal Control system components, pump package

Sub-Contractors (contd.)

NORD MICRO ELEKTRONIX Federal Republic of Germany	Avionics assembly
ODETICS United States	Digital recorder, mass memory
OKG (later replaced by VMW) Austria	Mechanical ground support equipment, viewport adaptor assembly, manifolds, nitrogen shut-off valve control
ROVSING Denmark	Computer software
STANDARD ELECTRIC LORENZ (SEL) Federal Republic of Germany	Remote acquisition units, caution and warning system
TERMA Denmark	Subsystem power distribution box
THOMPSON CSF France	Data Display System
VEREINIGTE FLUGTECHNISCHE WERKE (VFW) Federal Republic of Germany	Mechanical ground support equipment

4. Consultants

McDONNEL DOUGLAS and TRW
United States

Instrument Pointing System

DORNIER SYSTEMS Federal Republic of Germany	Prime Contractor

AFTER SPACELAB

EURECA

The Eureca payload carrier, now under development by ESA incorporates the more attractive features of Spacelab and conventional expendable satellites. In particular, it provides for:

1. relatively long duration flights (up to 6 or 8 months)
2. high power and mass capability for the payload
3. retrieval of samples and equipment at the end of a mission and re-use as required
4. no disturbances from a crew during the flight but manned attendance during launch for reliable set-up and operation, and
5. lower costs (compared with Spacelab and many conventional satellites since the system occupies only about 2.5 m of the Orbiter cargo bay.

The mission profile is as follows. The experiments are integrated on to the Eureca platform and their operation is checked. The whole system is then delivered to KSC in preparation for its launch by the Shuttle. In orbit, Eureca is removed from the Orbiter cargo bay and is boosted to about 500 km by its built-in mono-propellant engines (total thrust 80N). Solar arrays are used to provide electrical power for the experiments. After about 6 months Eureca is returned to a lower orbit for retrieval on a subsequent Shuttle flight.

The Eureca platform can carry payloads of up to 1000 kg with an electrical power supply of about one kilowatt. Undisturbed microgravity levels of 10-5g can be expected. The first flight of Eureca will be devoted mainly to the Microgravity Sciences (Material and Life Sciences). Launch is scheduled for early-1988 and retrieval in late-1988. Eureca is also very suitable for investigations in other disciplines such as Astronomy, Solar Physics, Atmospheric Physics, Remote Sensing and Technology.

The Eureca concept is important in two respects. Firstly, it can be used in its own right as a free-flying, recoverable carrier of orbital experiments. In this context its use can be foreseen over the period 1988-1995. Secondly, it could play an important role in Europe's association with the NASA Space Station since it can act in the attached or free-flying mode (co-orbiting with the Space Station or in polar orbit) as a man-tended, semi-permanent, payload carrier. This concept could grow out of the present Eureca with the development of suitable docking techniques. Such a use can be visualised as starting about 1993 and lasting beyond the end of the century.

TOWARDS A SPACE STATION

ESA'S LONG TERM PREPARATORY PROGRAMME

In order to prepare for the major decisions which Europe has to take in deciding the Space Transportation elements of the 1990's, ESA Member States have entrusted the Agency with the so-called Long Term Preparatory Programme (LTPP). Within this programme a number of industrial studies are being conducted for identifying projected STS user requirements, performing parameter analysis trades and preliminary concept definitions of candidate, future STS elements and providing preliminary cost estimates. This preparatory programme concentrates on two main elements:

- o future European launchers beyond Ariane 4, and
- o the build-up of a European In-Orbit Infrastructure (IOI) which will eventually permit Europe to master new capabilities which will determine the successful performance of future missions (e.g., orbital intervention for space assembly or repair, return to Earth of manufactured products).

The studies carried out so far in ESA's LTPP on its future IOI have centred around different ways of achieving an eventual European independent capability to conduct commercial missions; in particular, space processing in Low Earth Orbit. Solutions oriented towards complete automation would require fully automated large space platforms, which are resupplied with materials to be processed, spares for replacing failed equipment and fuel for orbit raising. Space-based supply and servicing vehicles would be necessary to assume these services, which could be docked to the platform. In addition, re-entry vehicles are necessary to return the processed products to Earth. Before such automated space factories could be operated on a large scale, a number of basic operational capabilities have to be established and demonstrated by Europe:

- o automated rendez-vous and docking,
- o high degree of automation and robotic support by manipulator arms,
- o re-entry capability.

In addition, periodic manned intervention is required for unforeseen actions which are difficult or impossible to achieve automatically. These periodic manned interventions could be performed by the crew of a European spaceplane launched by the future European launcher.

Major emphasis in the LTPP studies has been placed on the nearer-term goal of preparing for a European participation in the US Space Station programme. In this context, extensions of Spacelab and Eureca technologies have been applied to the study of manned laboratory modules and space platforms respectively.

THE US PROPOSAL FOR A SPACE STATION

The decision by US President Reagan in January 1984 to start a programme resulting in a permanently manned Space Station in the early 1990's and, in particular, the invitation to other countries to participate in the programme was received with much interest in Europe.

At the ESA Council Meeting at Ministerial level held in Rome on 30 and 31 January 1985, the Ministers of ESA Member States accepted the offer of the President of the United States, on the understanding that Europe was given responsibility for the design, development, exploitation and evolution of one or several important elements of the Station.

EUROPEAN INTEREST IN THE US OFFER

For the user community, a Space Station system will ensure the following major advantages:

- adequate resources (e.g., electrical power) and support to conduct experiments under relatively unconstrained conditions,
- nearly unlimited operation time, allowing the study of long-duration effects, e.g., on biological systems, and to fulfill the conditions required by certain space processing experiments,
- intervention and support by scientists if required.

THE COLUMBUS INITIATIVE

Germany and Italy have jointly undertaken studies at national level on the "Columbus Programme". The aim of these studies was to investigate participation options in the US Space Station and to elaborate a first programme proposal. This activity resulted in a proposal to ESA for the Europeanisation of the project. Based on this initiative, and on the results of ESA Space Station studies, authorisation was given to ESA by its Council in June 1984 to undertake a preparatory Space Station programme, based on the German/Italian proposal, and called "Columbus".

The Ministers of ESA's Member States, at the Council meeting held in Rome in January 1985, "welcomed and endorsed the proposal to undertake, in the field of in-orbit structures, the Columbus programme, as a significant part of an international space station programme".

The major elements of the Columbus programme are:

- space segment
- payloads
- ground segment
- demonstration missions

The baseline space segment comprises:

pressurised modules, derived from Spacelab, permanently manned when docked to the Space Station and man-tended when free-flying

platforms, either in solar orbit, mainly dedicated to Earth Observations, or, for a variety of disciplines, in orbit close to the Space Station from where they could be serviced by astronauts

resources modules, providing the resources required when the Columbus module is used as a free-flyer

a servicing vehicle, for support of free-flying modules or platforms.

Demonstration missions are foreseen in the early use of the Columbus space station operation.

EUROPEAN PARTICIPATION

Spacelab and Eureca represent solid investments for the future. Europe can build on the engineering and technical experience gained through its involvement with these two programmes. Spacelab lends itself to being developed into an essential part of the permanently manned Space Station and the basic Eureca principles can lead to an unmanned platform which can be visited by Shuttle astronauts from time-to-time when free-flying or which can be serviced at the Space Station when docked.

Following negotiations between ESA and NASA, a plan of activities to be undertaken on both sides of the Atlantic between 1985 and 1987 has been drawn up. During this period each partner will carry out, in parallel, detailed definition studies (phase B studies) on a number of Space Station elements.

According to present planning, NASA intends to develop a permanently manned Space Station consisting of several pressurised modules and unpressurised areas. Potential elements of ESA's contribution could consist of a pressurised module that could be used as a manned laboratory, of free-flying payload carriers for both low inclination and polar orbits which will be used for experimental purposes, of a servicing vehicle and a resources module which could provide both the pressurised module and the platforms with electric power, and cooling and stabilising systems.

In addition, ESA-managed studies will also cover such aspects as ground facilities for mission preparation and support, and a data transmission system.

The cost of the Phase B studies carried out by European industry under ESA management, together with the corresponding technology programme amounts to 80 MAU* (mid-1983 price levels, 1984 exchange rates).

The ESA Council, at its meeting on 24/25 April 1985, unanimously authorised the Director General to sign with NASA the Memorandum of Understanding which lays down the terms and conditions under which the cooperative effort will be carried out. The document was finally signed by ESA Director General, Prof. R. Lust and NASA Administrator, Mr. J. Beggs, on 3 June 1985.

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*MAU - Million Accounting Units
1 AU = $0.8 at 1985 exchange rates